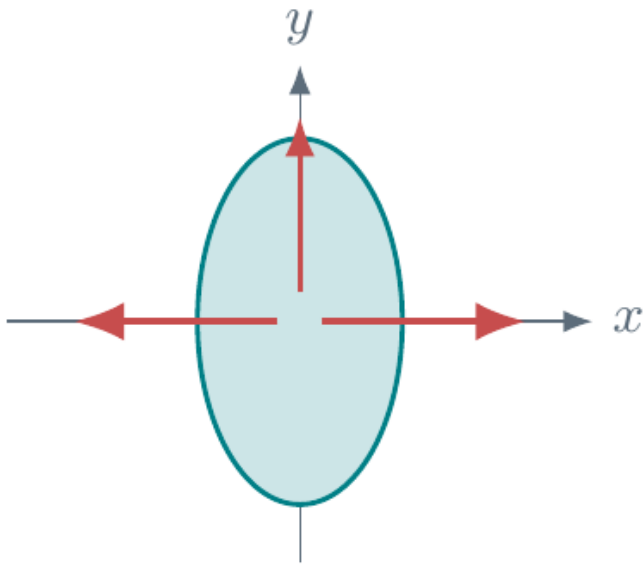

J/ ψ elliptic flow in pp and 00 collisions with ALICE

Senjie Zhu (ALICE Collaboration)

Oct. 29, 2026

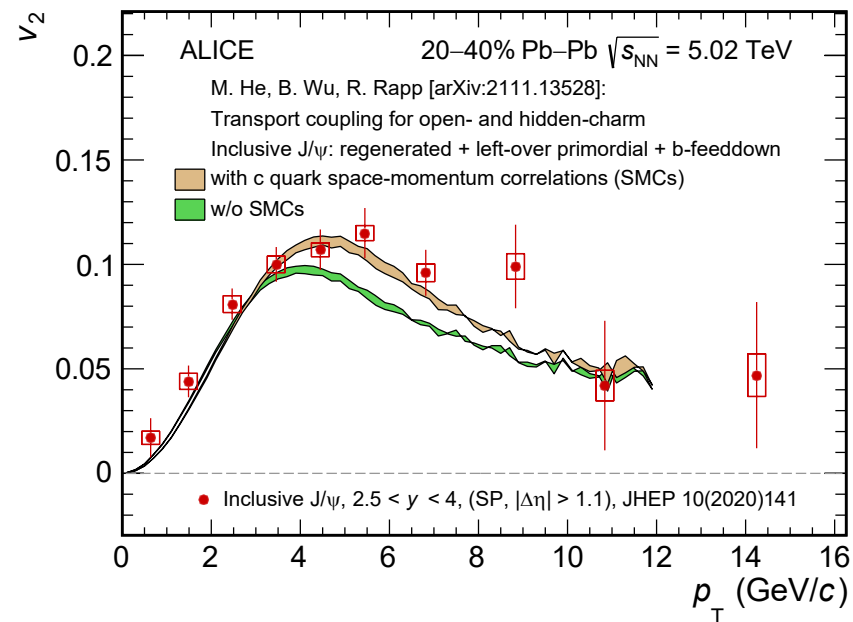


J/ψ anisotropy and collective dynamics



$$\frac{dN}{d\varphi} \propto 1 + 2 \sum_{n=1}^{\infty} v_n \cos[n(\varphi - \Psi_n)],$$

$$v_2 = \langle \cos[2(\varphi - \Psi_2)] \rangle.$$



ALI-PUB-500427

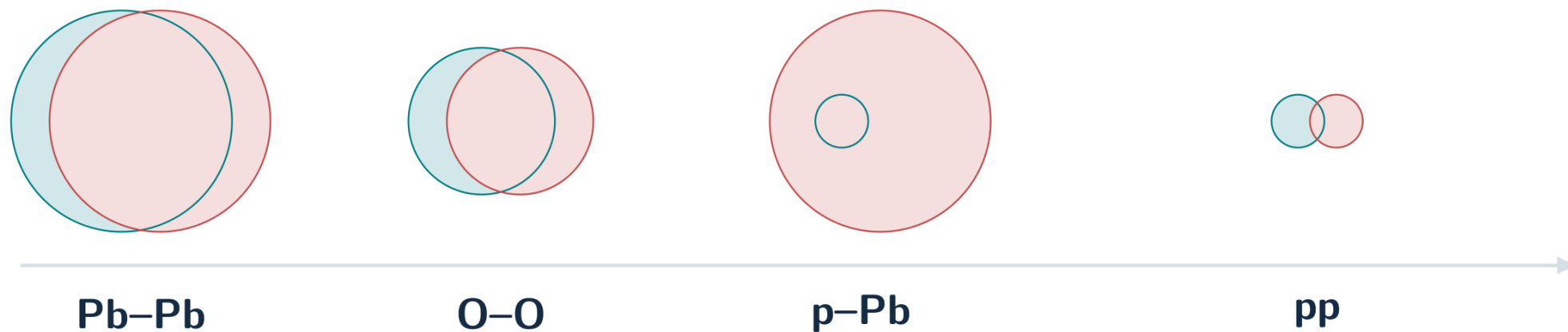
Regeneration

Recombining charm quarks can transfer their anisotropy to J/ψ.

Survival and energy loss

Different interaction lengths can generate an anisotropic surviving yield.

J/ ψ anisotropy as a probe of the medium



Geometry

Overlap shape and event-by-event fluctuations.

Medium evolution

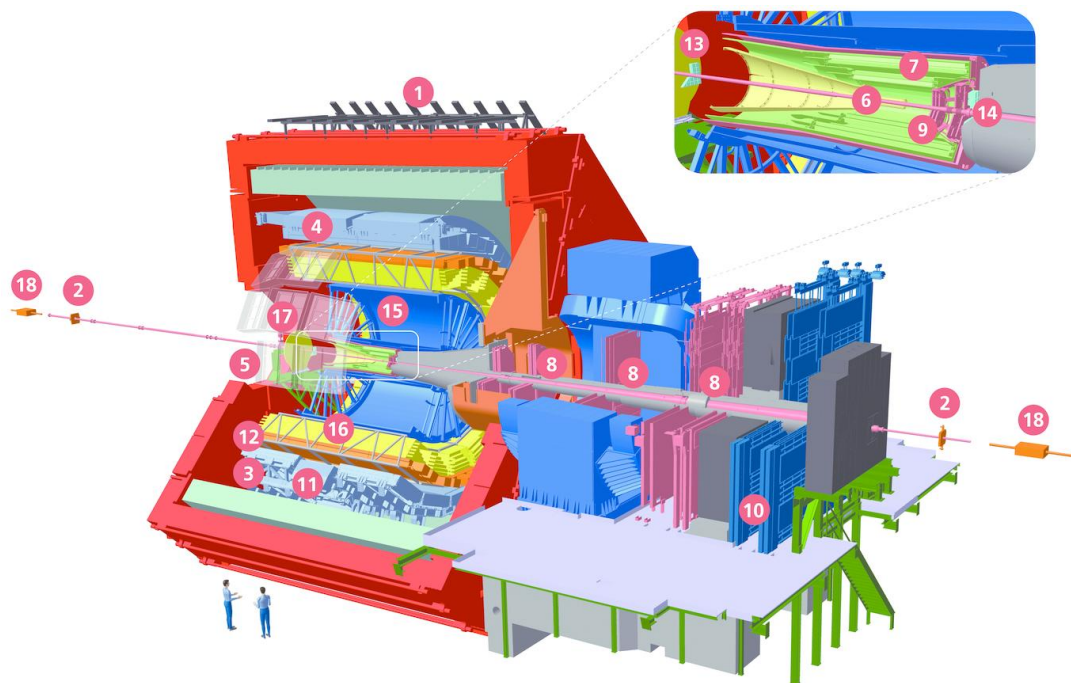
Collective expansion, density and interaction time.

Charmonium probe

Survival and regeneration can probe medium evolution.

- **J/ ψ anisotropy can probe medium dynamics across collision systems.**

The ALICE detector



Muon spectrometer

$J/\psi \rightarrow \mu^+\mu^-$; $2.5 < y < 4$ in symmetric systems.

Central barrel

ITS and TPC: $J/\psi \rightarrow e^+e^-$; $|y| < 0.9$.

Forward detectors

FT0A: event plane

FT0C: event plane, O–O centrality in Run 3.

ALICE, arXiv:2511.10311, Fig. 1; alice.cern/alice-detectors. Run 2 and Run 3 differ.

Scalar-product normalization with three subevents

$$v_n = \frac{\langle u_n \cdot Q_n^A / M^A \rangle}{\sqrt{\frac{\langle Q_n^A / M^A \cdot Q_n^B / M^B \rangle \langle Q_n^A / M^A \cdot Q_n^C / M^C \rangle}{\langle Q_n^B / M^B \cdot Q_n^C / M^C \rangle}}$$

- Q^A : from TPC
- Q^B : from FT0A
- Q^C : from FT0C

Candidate and reference vectors

$$u_n = e^{in\varphi}, \quad Q_n = \sum_j w_j e^{in\varphi_j}.$$

Reference normalization

A–B, A–C and B–C reference-vector correlations determine the denominator.

Analysis requirements

Correct detector acceptance. Evaluate reference correlations in narrow centrality intervals.

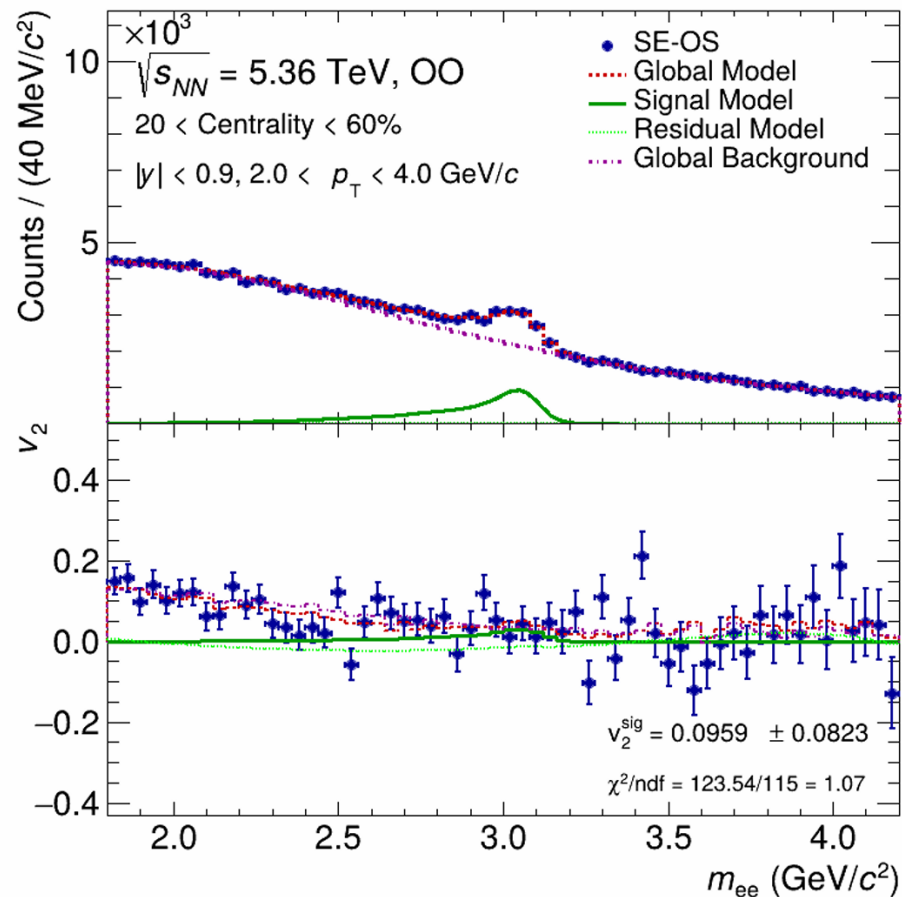
Rapidity separation

Suppress short-range correlations and avoid correlations with decay daughters.

Real parts are understood. Candidate averages and event averages follow the published convention.

ALICE, JHEP 10 (2020) 141, Eq. (2). Published Run 2 definition and averaging convention.

Signal extraction example in 0–0



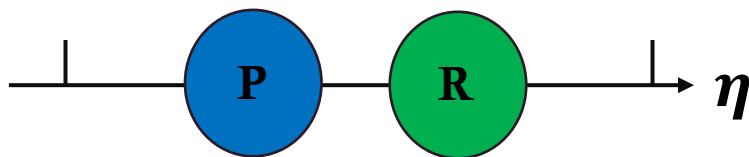
Simultaneous fit for signal extraction

$$v_2^{\text{tot}}(M_{ee}) = \frac{x(M_{ee})}{1 + x(M_{ee})} v_2^{\text{Sig}} + \frac{1}{1 + x(M_{ee})} v_2^{\text{Bkg}}(M_{ee}),$$

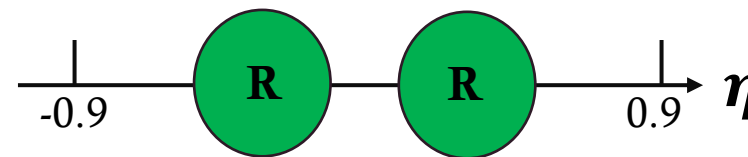
v_2 background from mix-event

$$v_2(p_T, \text{cent}, M_{ee}) = \frac{\langle v_2^1 \cos[2(\varphi_1 - \varphi)] \rangle + \langle v_2^2 \cos[2(\varphi_2 - \varphi)] \rangle}{1 + \langle v_2^1 v_2^2 \cos[2(\varphi_1 - \varphi_2)] \rangle},$$

Two particle correlation method



PARTICLE OF INTEREST (**POI**): $V'_{n,2} = v_n v'_n$



REFERENCE (**REF**): $V_{n,2} = v_n^2$

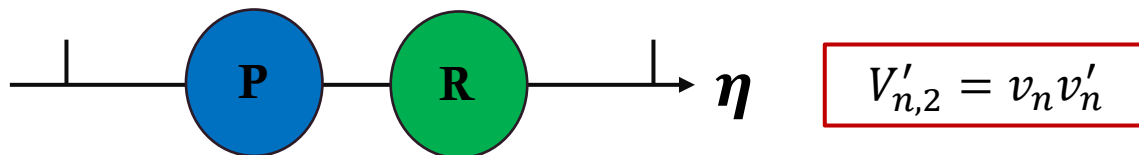
$$v_n v'_n = \langle \cos n(\phi - \psi) \rangle$$

$$v_n^2 = \langle \cos n(\phi_1 - \phi_2) \rangle$$

- v_n : the n -th harmonic coefficient of REF
- v'_n : the n -th harmonic coefficient of POI
- ϕ : azimuthal angle of reference flow
- ψ : azimuthal angle of J/ψ

J/ψ harmonic coefficient: $v_2^{J/\psi} = \frac{V'_{2,2}}{\sqrt{V_{2,2}}}$

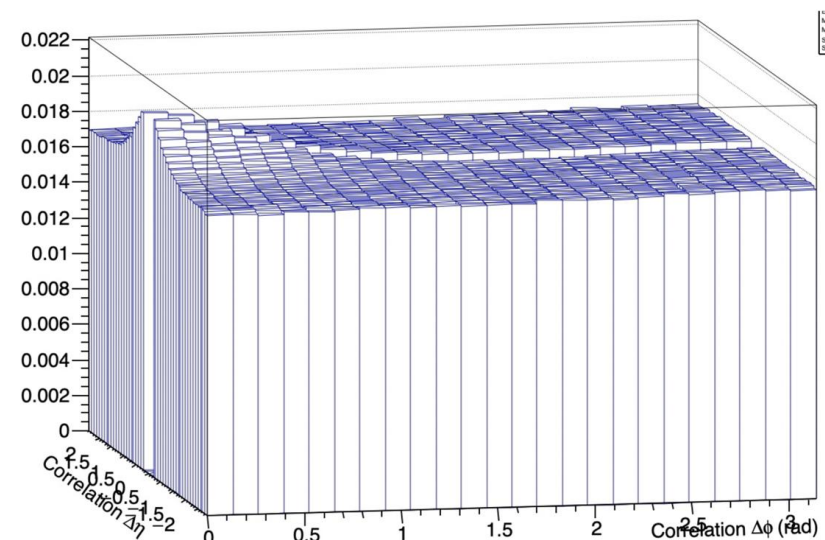
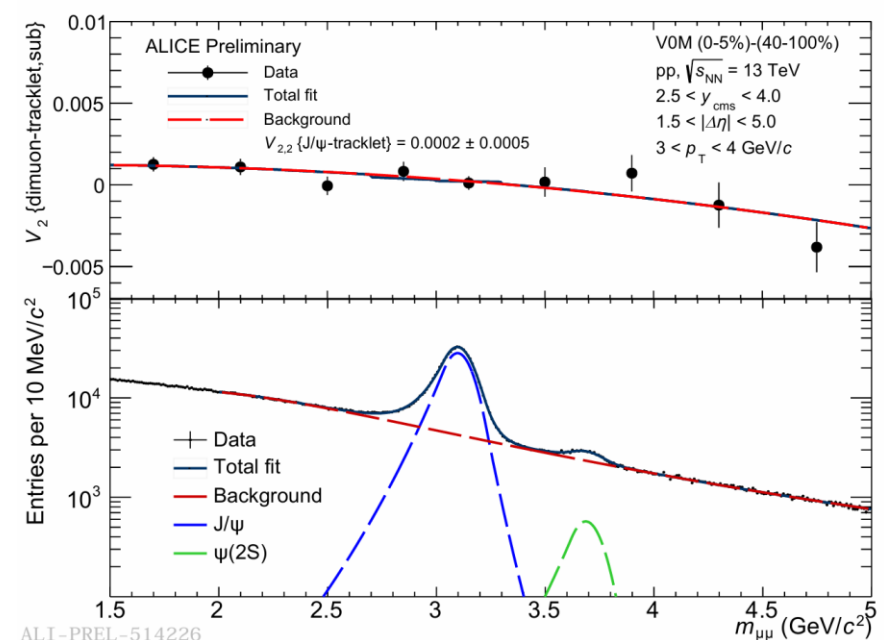
Two particle correlation method



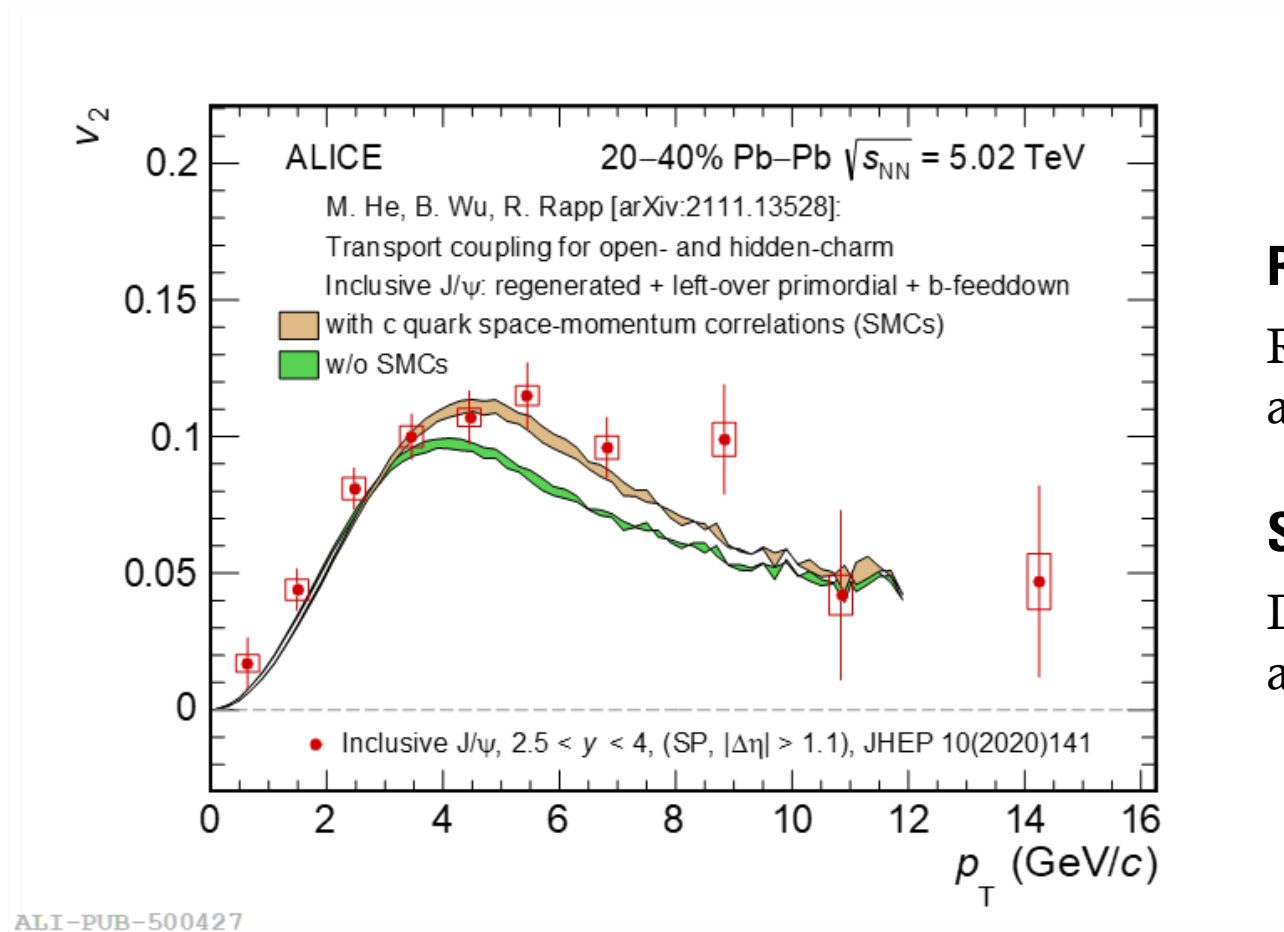
PARTICLE OF INTEREST (**POI**): J/ψ candidate
Reference (**REF**): ITS tracklets

Associated yield is defined as:

- $S(\Delta\phi, \Delta\eta) = \frac{1}{N_{trig}} \frac{d^2 N_{same}}{d\Delta\eta d\Delta\phi}$: the associated yield per trigger particle from the same event.
- $B(\Delta\phi, \Delta\eta) = \alpha \frac{d^2 N_{mixed}}{d\Delta\eta d\Delta\phi}$: A correction for pair acceptance and pair efficiency, α is the normalization factor.



Pb–Pb: a published transport-model benchmark



Regeneration

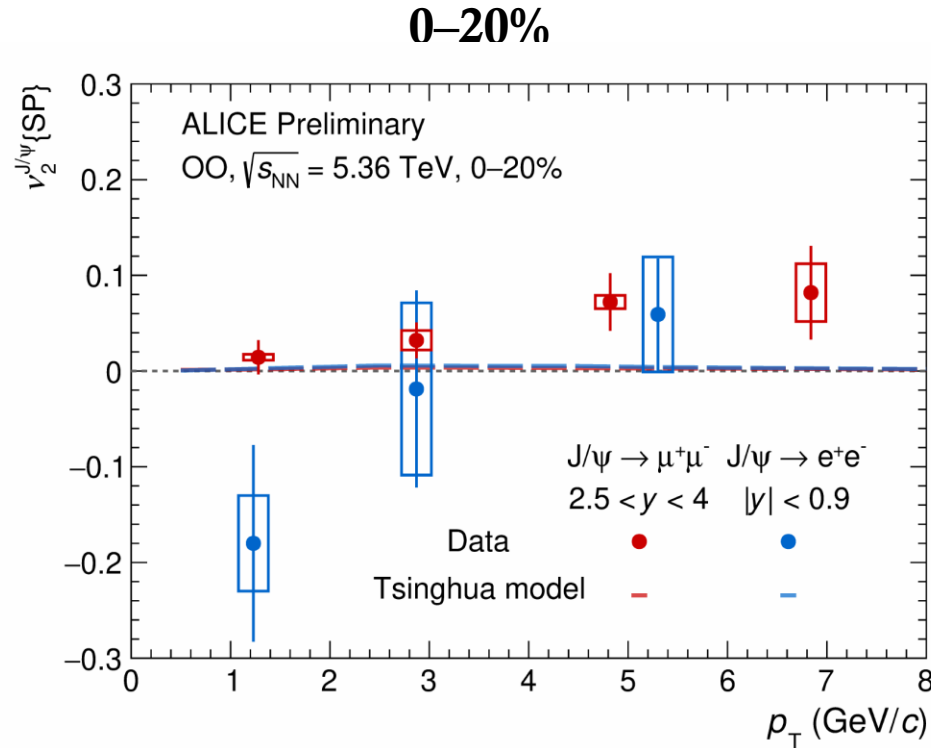
Recombining charm quarks can transfer their anisotropy to J/ψ.

Survival and energy loss

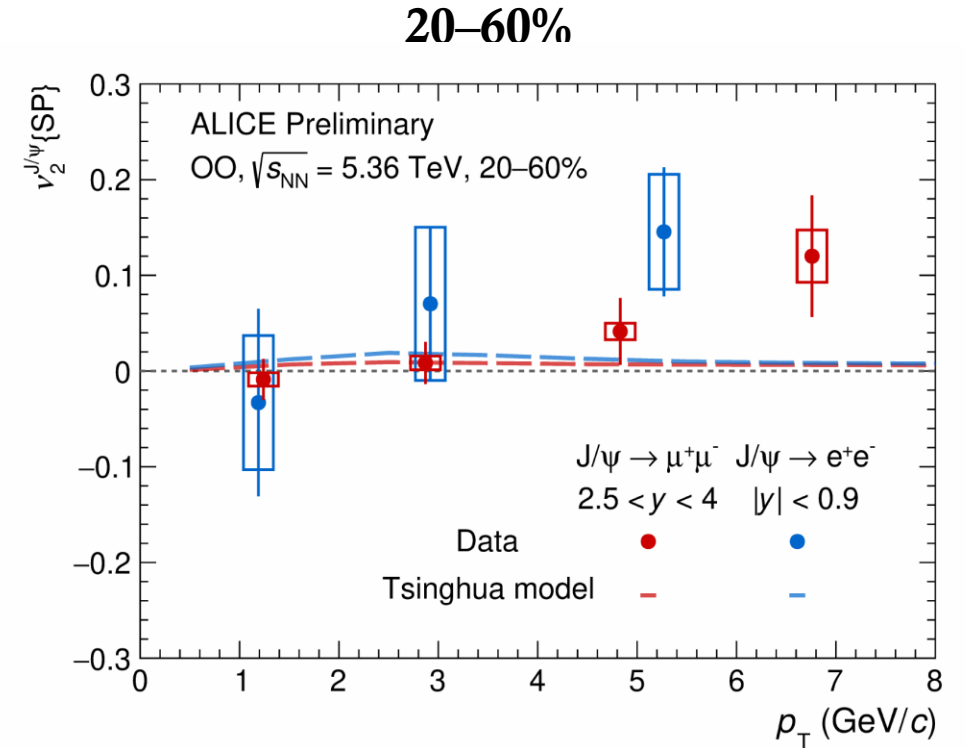
Different interaction lengths can generate an anisotropic surviving yield.

ALICE data: JHEP 10 (2020) 141. Model: M. He, B. Wu, R. Rapp, arXiv:2111.13528. Figure: ALI-PUB-500427.

0–0: comparison with the Tsinghua calculation



ALI-PREL-638579

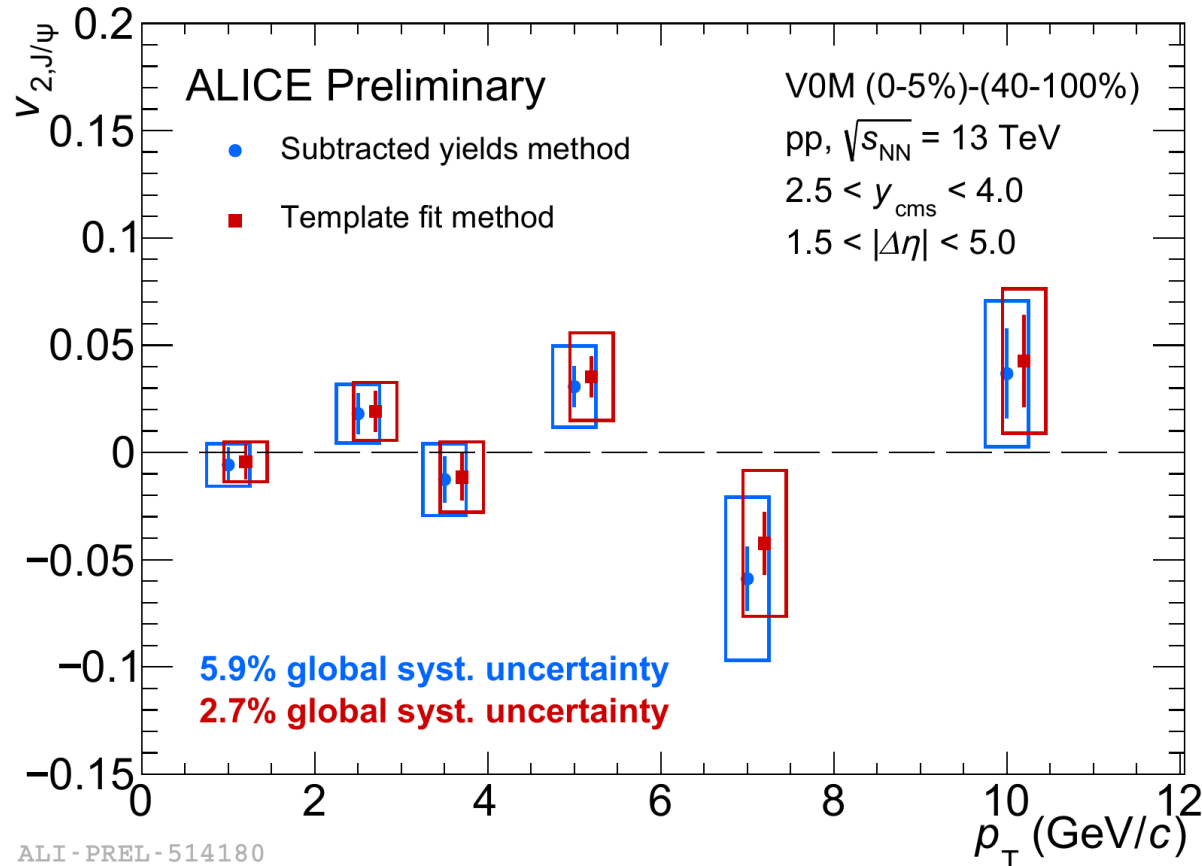


ALI-PREL-638584

- Higher- p_T forward points tend to exceed the displayed Tsinghua curves.
 - Tsinghua: MUSIC + transport
- Midrapidity uncertainties limit conclusions about rapidity dependence.

ALICE Preliminary, ALI-PREL-638579 and ALI-PREL-638584. Qualitative comparison.

pp: integrated v_2 compatible with zero



pp at 13 TeV in forward rapidity

Forward J/ ψ ; V0M 0–5% with 40–100% as the reference.

Two subtraction strategies

Yield subtraction and template fits give compatible results.

Measurement precision

No significant p_T trend; the integrated result is compatible with zero.

ALI-PREL-514180

ALICE Preliminary, QM2022, ALI-PREL-514180. Global uncertainties in original figure.

Conclusions: J/ψ elliptic flow in pp and O–O

- O–O at 5.36 TeV
 - Higher- p_T forward results tend to exceed the displayed Tsinghua curves.
 - Midrapidity uncertainties limit conclusions about rapidity dependence.
- pp at 13 TeV:
 - The integrated forward J/ψ v_2 is compatible with zero within current precision.

pp: ALI-PREL-514180 (QM2022). O–O: ALI-PREL-638579, 638584. Qualitative model comparison.
